

# A Visually Lossless Data Compression Technology for Space Applications

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# CONTENT

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- **Summary of Lossless Compression Development**
- **High Performance Compression:**
  - **Requirement for Space Applications**
  - **GSFC/NASA Technique**
  - **Performance**
    - **Comparison with current JPEG**
    - **Performance on CCSDS Test Image Set**
    - **Visual Evaluation**
  - **Technology Status**
  - **Conclusion**

# Lossless Data Compression for Space Applications

## *Benefits for NASA Missions*

- Reduces bandwidth requirement, onboard storage or station contact time
- Reduces ground archive volume with savings in \$\$M

## *Technology Features*

- Algorithm adopted as CCSDS recommendation
- Works well with large data quantization range and packet data system without penalty on performance
- ASIC offers real-time operation  $> 20$  Msamples/sec in space environment
  - Compresses faster and better than commercial techniques

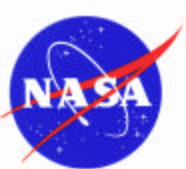


Lossless Compression Board

## *Users*

SWAS/SMEX, MAP/MIDEX, VCL, EOS-CHEM, KOMPSAT, IMAGE, CASSINI, INTEGRAL, SERTS, SBIRS/DOD, COBRA/DOE, MARS ODYSSEY, NPP, EO3, EOSDIS(HDF)

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# REQUIREMENTS FOR SPACE APPLICATIONS

Requirements established by Consultative Committee for Space Data Systems (CCSDS) Compression Working Group in 1998:

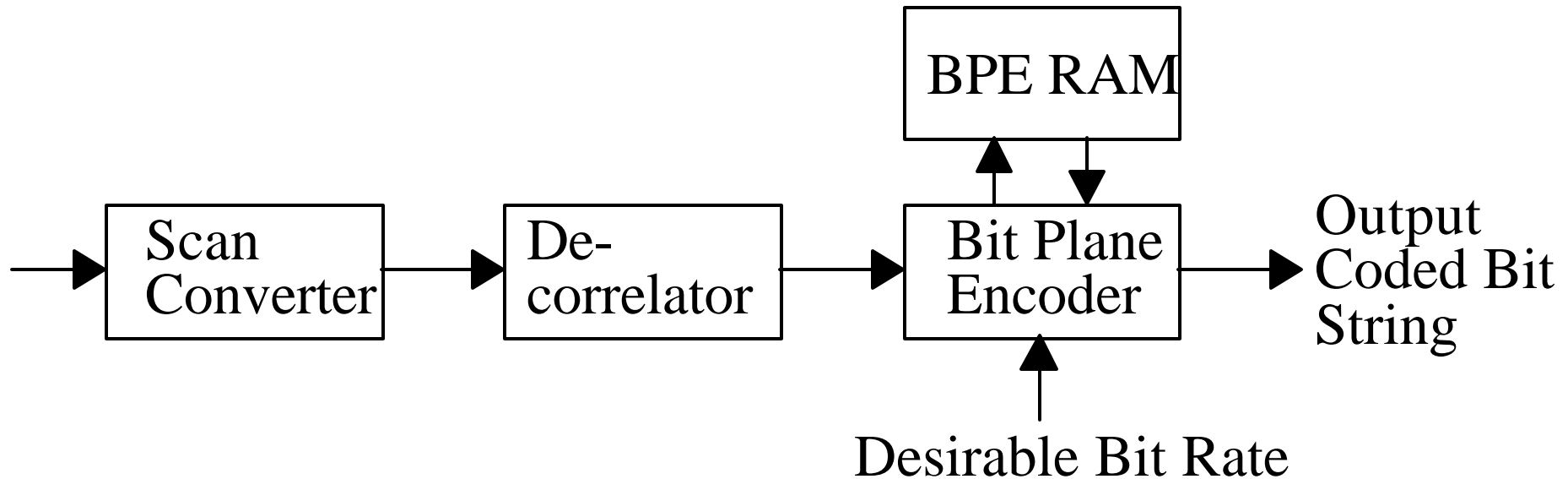
- Process both non-frame based (push broom) and frame based input source data.
- Offer adjustable data rate.
- Work with large source quantization ranges up to 16 bit-per-pixel
- Offer real-time processing  $\geq 20$  Msamples/sec,  
at  $\leq 1$  watt/Msamples/sec.

The power consumption includes all buffering and support electronics.

- Require minimum ground interaction during operation.
- Allow packetization for error containment.



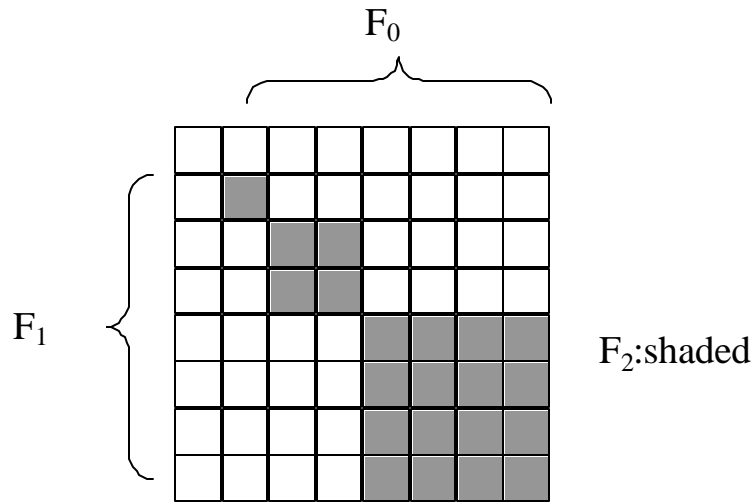
# GSFC/NASA TECHNIQUE



De-correlator: EDCT (DCT+MLT), 2DMLT



# BIT PLANE ENCODER



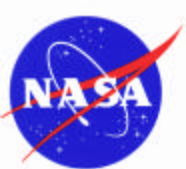
Scanning on each bit plane

Direction:  $F_0 \Rightarrow F_1 \Rightarrow F_2$

Coding: 3 main levels/block

Output: embedded bit string

$\Rightarrow$  progressive decoding

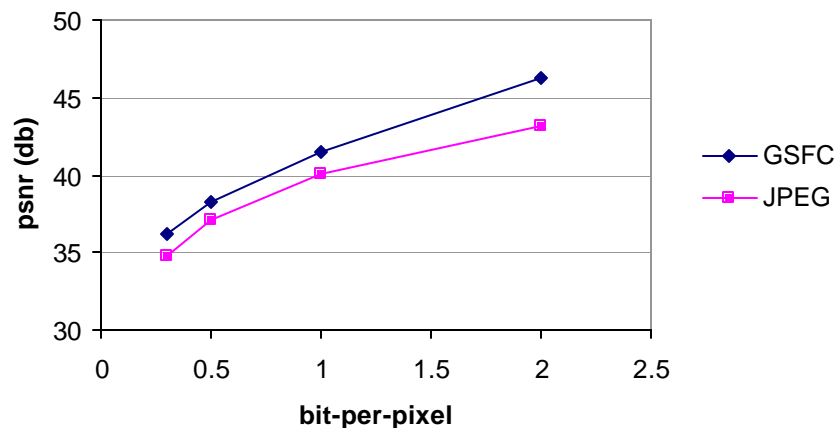


# PERFORMANCE

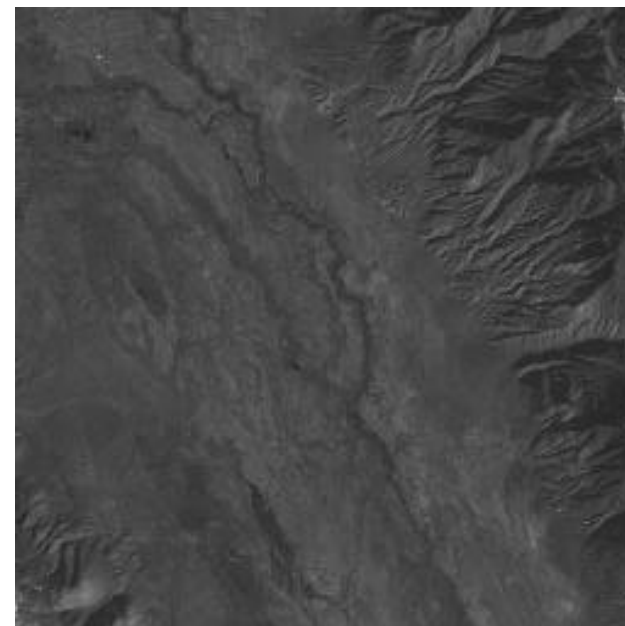
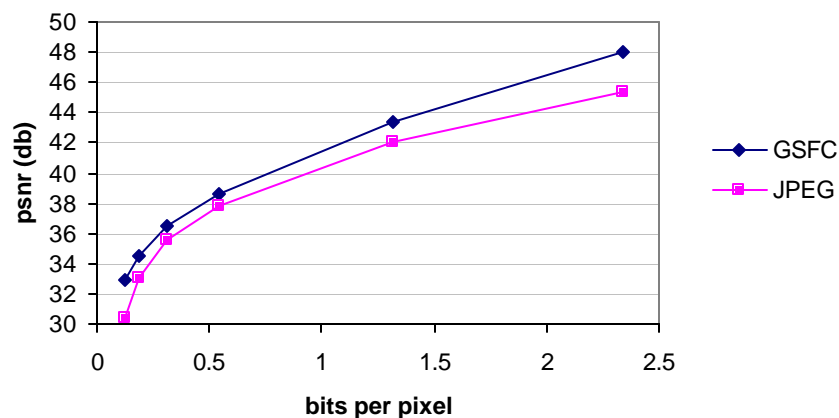
## Comparison with Current JPEG

EDCT

StripMode



Frame Mode



8-bit Landsat Image



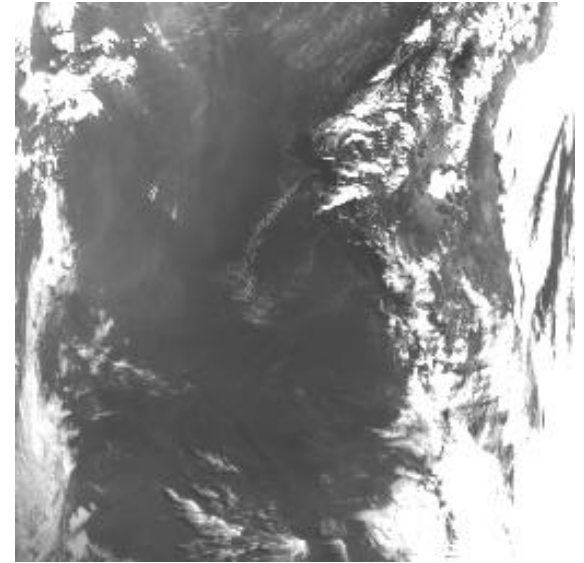
# TEST IMAGES



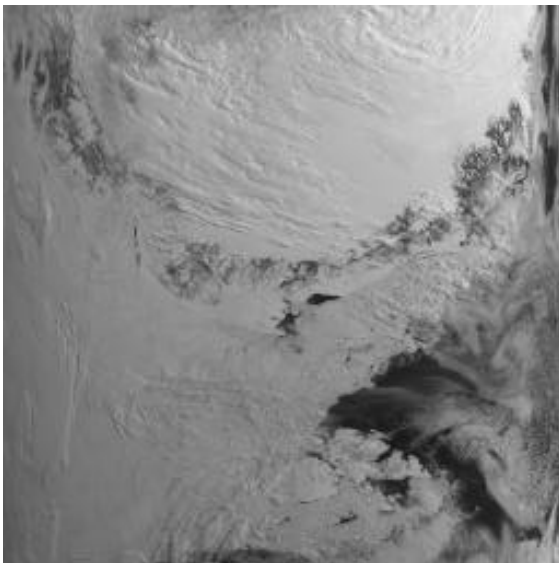
**Mars**



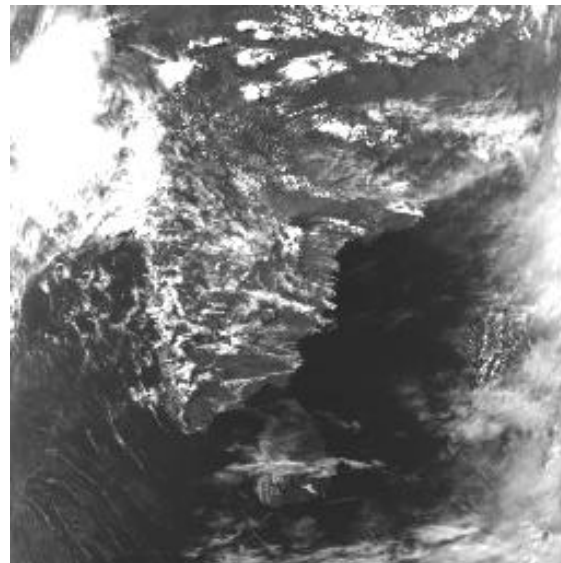
**SPOT**



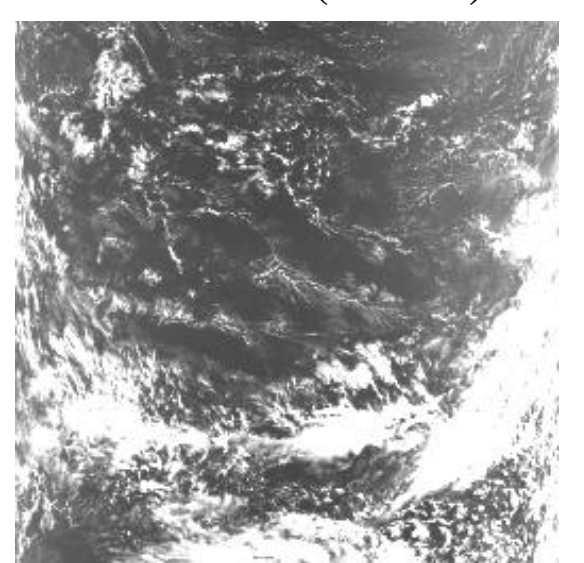
**FOREST(AVHR)**



**ICE(AVHR)**



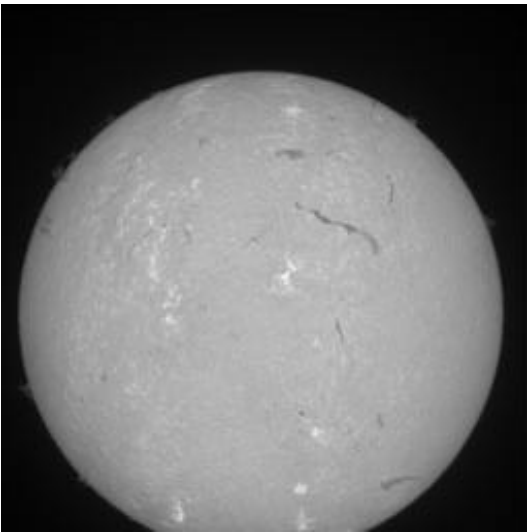
**INDIA(AVHR)**



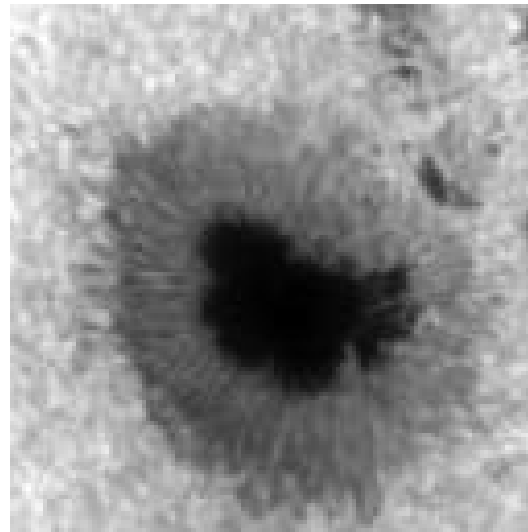
**OCEAN(AVHR)**



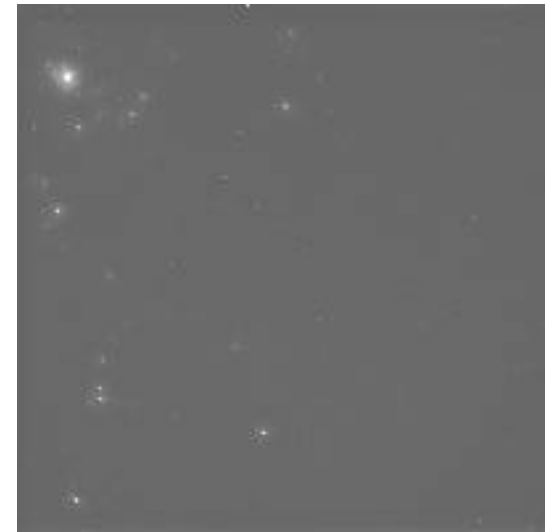
# TEST IMAGES



**SOLAR**



**SUNSPOT**



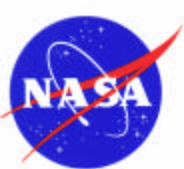
**WFPC**



**FOC**



**SAR**



# PERFORMANCE

## Performance on CCSDS Test Image Set (PSNR)

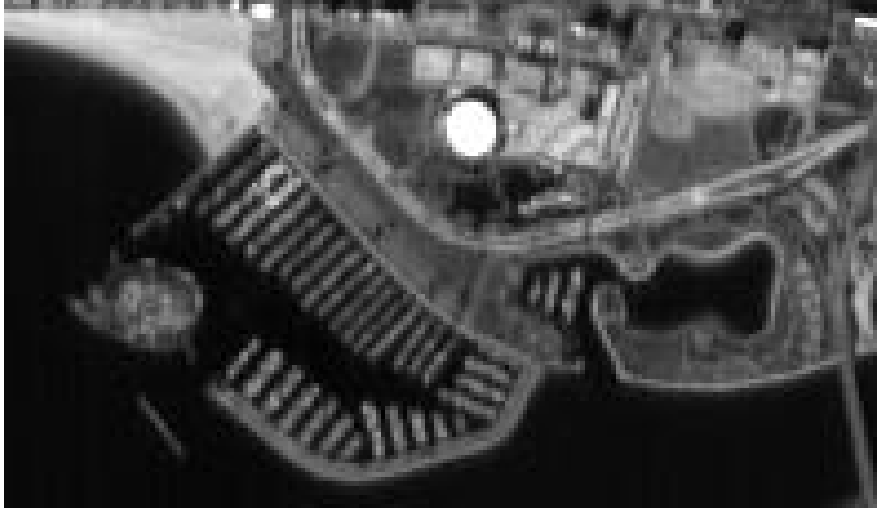
Image	size	bits/pixel	2DDCT bpp 1.0	EDCT bpp 1.0	2DMLT bpp 1.0	2DDCT bpp 0.5	EDCT bpp 0.5	2DMLT bpp 0.5
mars	512x512	8	33.8	34.5	35.0	29.4	29.9	30.5
Spot_panchr	1000x1000	8	37.9	38.2	38.7	34.4	34.6	35.0
Forest(avhrr)	2048x2048	10	48.1	48.4	48.8	42.5	42.8	43.3
Ice(avhrr)	2048x2048	10	45.8	46.3	46.7	41.3	41.8	42.2
India(avhrr)	2048x2048	10	42.5	43.0	43.3	37.5	37.9	38.4
Ocean(avhrr)	2048x2048	10	43.5	43.8	44.0	38.8	39.2	39.5
solar	1024x1024	12	48.6	49.0	49.4	44.4	44.7	45.2
Sunspot	512x512	12	54.2	54.6	55.0	50.2	50.9	51.6
Wfpc(hst)	800x800	12	68.4	67.8	66.3	66.2	64.5	60.1
Foc(hst)	1024x512	12	67.1	66.8	66.4	64.4	64.2	62.1
SAR	512x512	16	53.0	53.1	53.2	49.9	49.7	49.5

**EDCT Performance comparable to JPEG2000 “precinct height 8”**



# PERFORMANCE

## Visual Evaluation Performed at 1.0 bpp



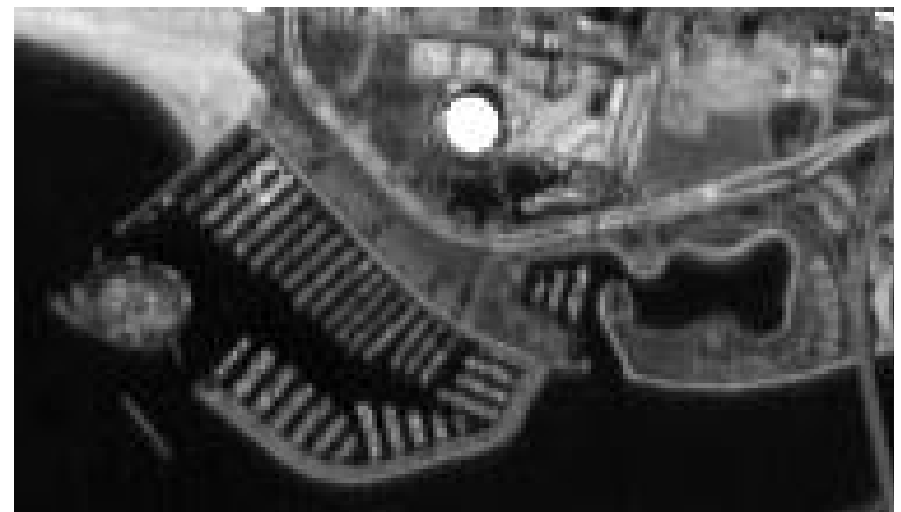
**Original**



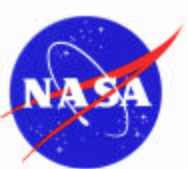
**2DDCT**



**EDCT**

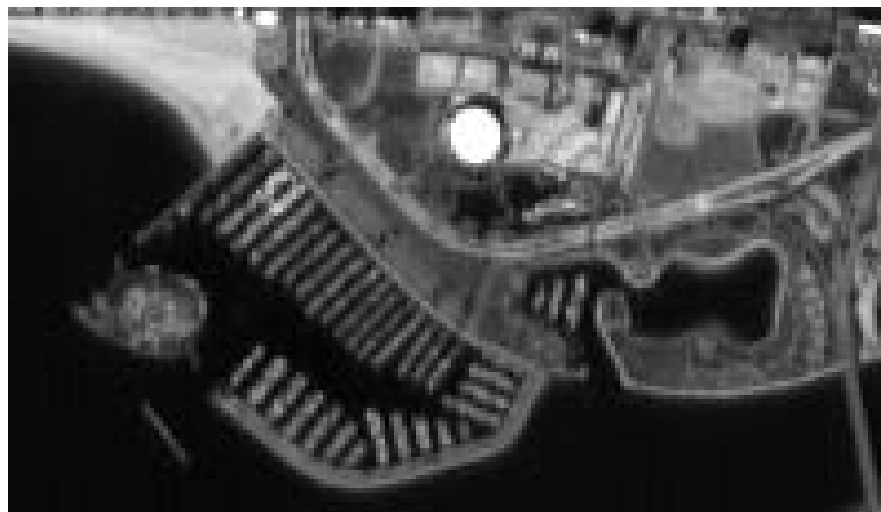


**2DMLT**

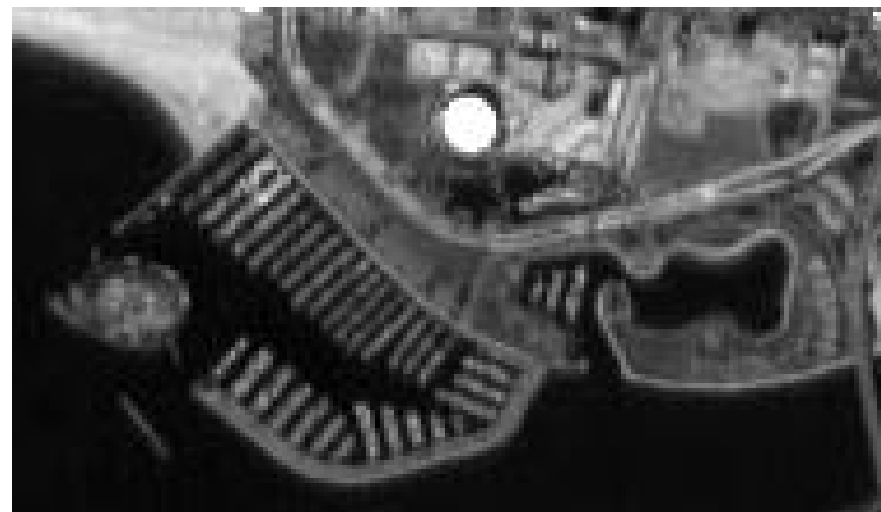


# PERFORMANCE

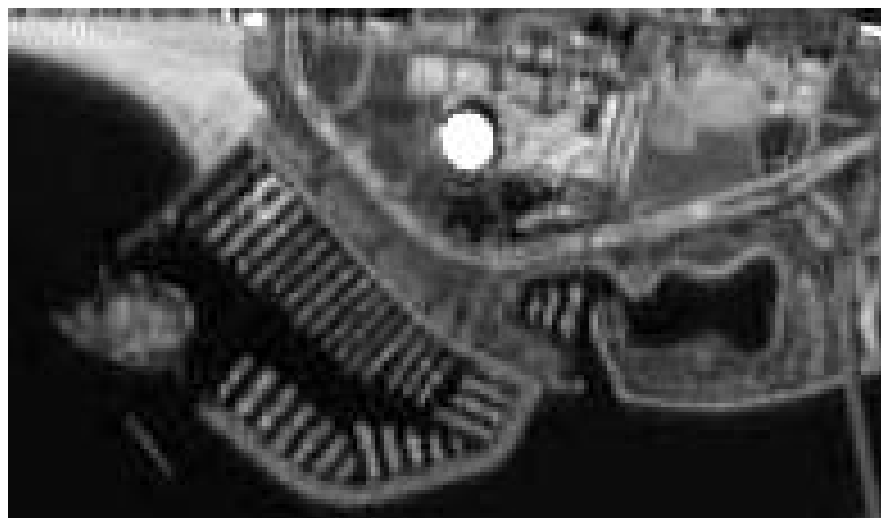
## Visual Evaluation Performed at 1.0 bpp



**Original**



**2DMLT**



**JPEG**

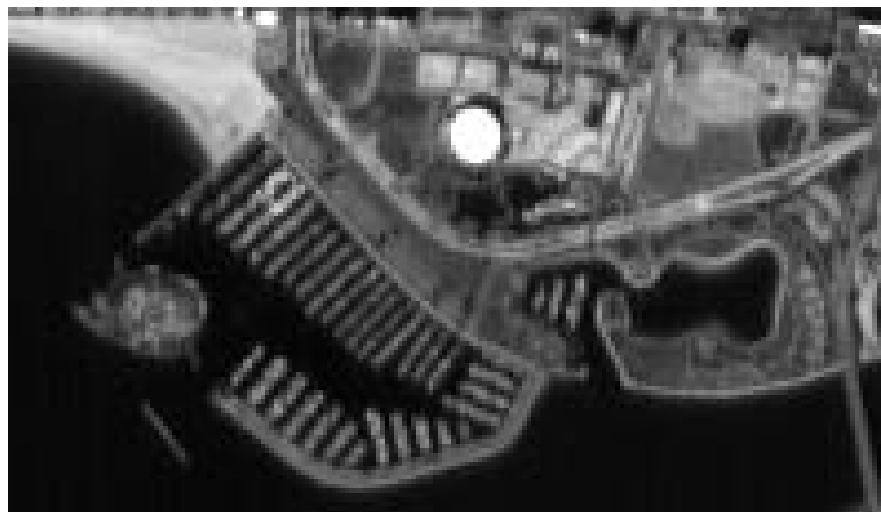


**JPEG2000**

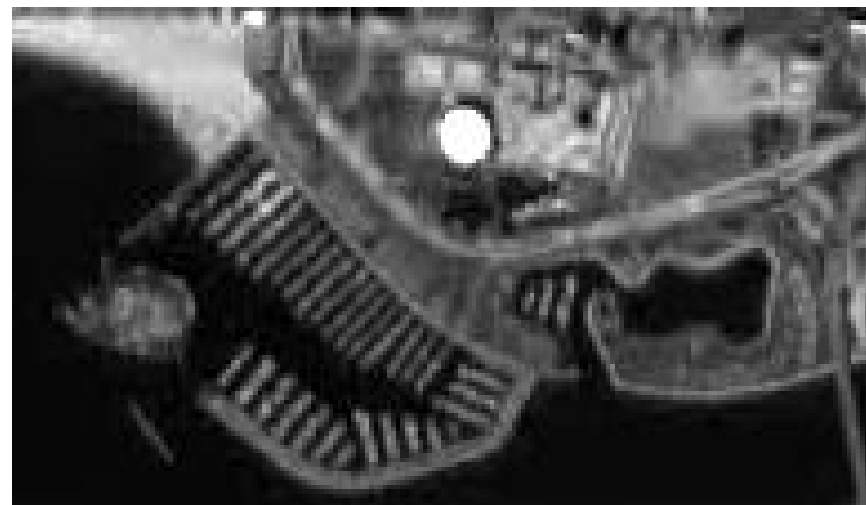


# PERFORMANCE

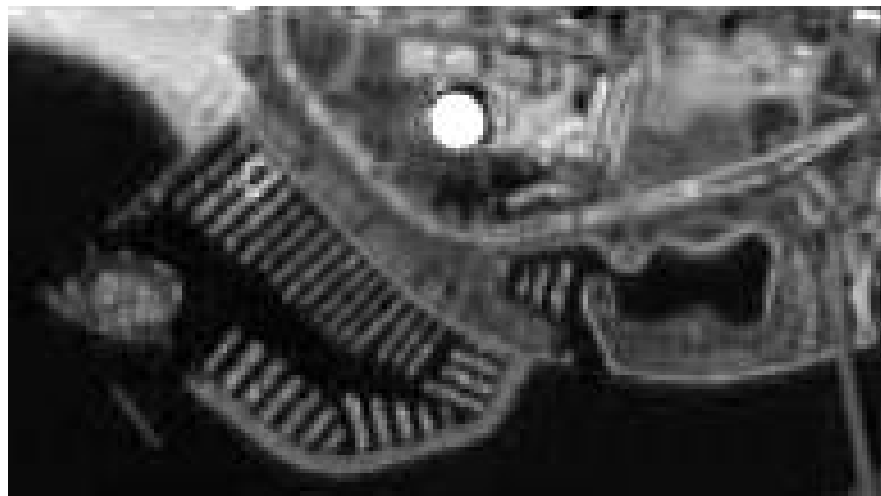
## Visual Evaluation Performed at 0.5 bpp



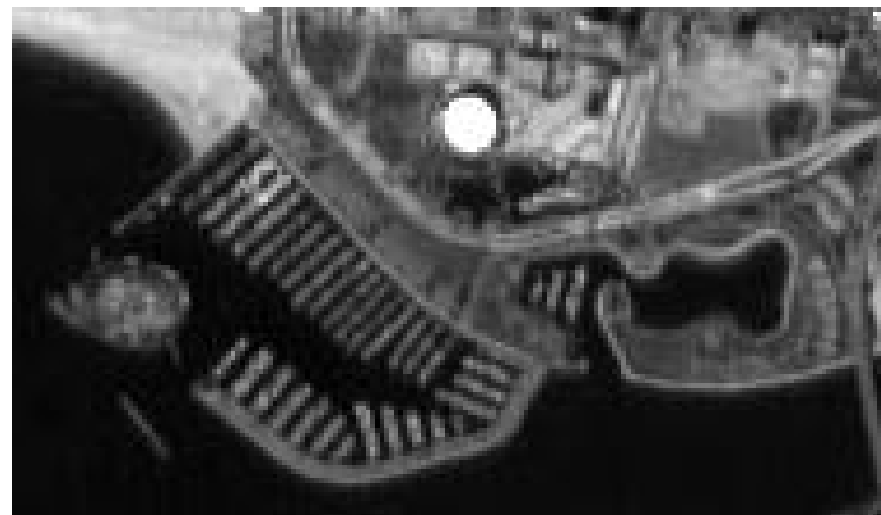
**Original**



**2DDCT**



**EDCT**

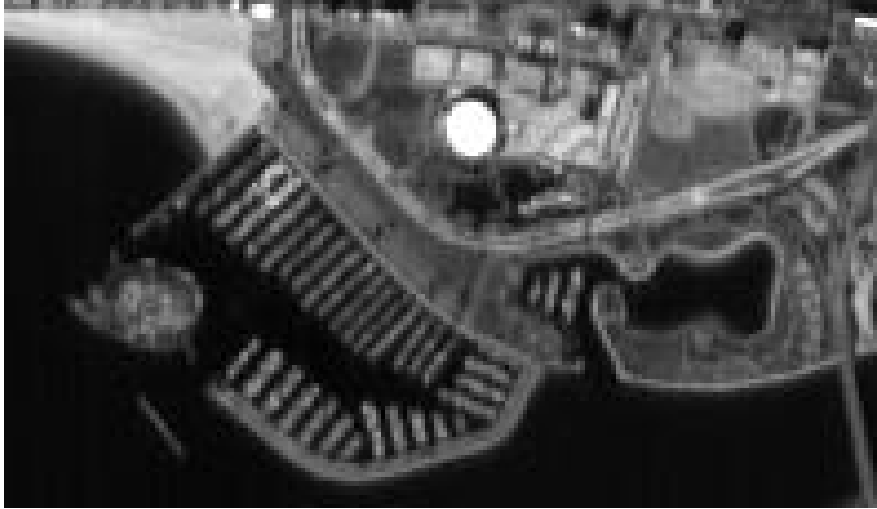


**2DMLT**



# PERFORMANCE

## Visual Evaluation Performed at 0.5 bpp



**Original**



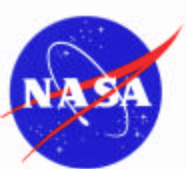
**2DMLT**



**JPEG**



**JPEG2000**



# PERFORMANCE

## Visual Evaluation Performed at 1.0 bpp



**Original**



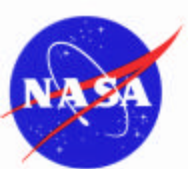
**2DMLT**



**JPEG**



**JPEG2000**



# PERFORMANCE

## Visual Evaluation Performed at 0.5 bpp



**Original**



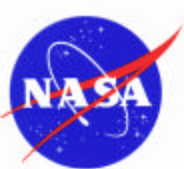
**2DMLT**



**JPEG**



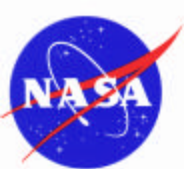
**JPEG2000**



# TECHNOLOGY STATUS



- **Earlier version on Lewis for Hyper-Spectral-Imager (data cube compression, 97)**
- **DCT/EDCT chip fabricated, tested at 35 Msamples/sec**
- **2D MLT chip planned 2002 design/fabrication**
- **Bit Plane Encoder chip under design ==> 2002 fabrication**
- **System power estimated at 0.36 watt/Mpixel/sec**
- **Software simulation performed on various types of images**
- **Performance impact on science product under study**
  - sea surface temperature --on NOAA-14 data,  
mean error < 0.01k from 0.25 - 2 bpp, 5/00
  - cloud detection using MODIS algorithm -- present



# CONCLUSION

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- **A visually lossless compression technique for space pushbroom/frame applications is being developed.**
- **The technique is implementable in current rad-tolerant, SEU/SEL immune electronics technology to achieve  $\geq 20$  Mpixels/sec and  $\leq 1$  watt/Mpixels/sec.**
- **The technique produces embedded bit string, allows accurate rate control, requires no table upload.**
- **Performance on quantitative measurement and visual evaluation is comparable to JPEG2000.**
- **Further study will be performed on possible impact on science product.**
- **The algorithm is a candidate for CCSDS recommendation.**